

## ***Interactive comment on “Analyzing precipitationsheds to understand the vulnerability of rainfall dependent regions” by P. W. Keys et al.***

**P. W. Keys et al.**

patrick@keysconsultinginc.com

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We would like to thank Paul Dirmeyer for his positive attitude towards the paper and interesting suggestions. Below we reply in detail to his comments.

1. Comment: “10489, L17-19: Foley et al. (2011) would be another good citation to motivate this work: <http://www.sciencemag.org/content/309/5734/570.abstract>”

Response: We are not entirely sure which paper the reviewer intended to point out. The link above links to Foley et al (2005), whereas there was also a recent publication by Foley et al. (2011) in Nature, which was published after our discussion paper was accepted and thus could not be referred to in this discussion paper. In the revised version we will include a citation to Foley et al. (2011), because this seems the best

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citation to motivate our work.

2. Comment: “10493, L18-23: Full resolution ERA-Interim data are now publicly available: [http://data-portal.ecmwf.int/data/d/interim\\_full\\_daily](http://data-portal.ecmwf.int/data/d/interim_full_daily) - do you feel there would be any sensitivity of the results to the resolution of the driving data?”

Response: We thank the reviewer for pointing this out. However, based on the method employed in this analysis, particularly smoothing of inter-annual variations by taking the average across multiple growing seasons, the authors suggest that the analysis will have a low sensitivity to higher resolution driving data. An advantage of the higher resolution data, however, will be that future analyses will be able to match land-use characteristics more closely with the atmospheric processes aloft – which will ultimately benefit any analysis exploring whether land-use changes are related to changes in moisture recycling.

3. Comment: “Fig 2: It is very difficult to discern the blue lines. Maybe it would be better to use black lines, and change the color scale for recycling ratio so it does not contain black.”

Response: These are good suggestions by the reviewer, and we will make the recommended adjustments to the figure.

4. Comment: “10495, L11-12: Please indicate the proportion of each grain. I suspect a smaller fraction of global maize is represented in these specific areas than the other two.”

Response: The areas of the three grains have been combined into a single area, however, we can provide the individual percentages of global cultivation of these cereals. Based on this feedback, the data were reanalyzed, and the percent of cultivated hectares of water-constrained, rainfed crops (maize, millet, and sorghum) has been revised upward. We will rewrite as follows: “Also, these seven sink regions contain 53% of the globally cultivated hectares of rainfed maize (29%), millet (70.5%), and sorghum

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(38%) occurring in water-constrained regions.”

5. Comment: “Fig 3: Please zoom in the map so it just encompasses the colored area, so readers can better see the detail, especially close to the sink region where the confidence should be highest.”

Response: We have chosen to display each precipitationshed on a (nearly) global map (see also Figures S1-S7) so that we are able to compare them roughly relative to each other. The figures are high resolution so that a reader is able to zoom in closely to examine the details.

6. Comment: “Fig 3a and Sec 4.3: I highly suspect that the large source region around the Mediterranean is bogus. We encounter the same situation when identifying source regions (analogous to precipitation-sheds) with the quasi-isentropic back-trajectory (QIBT) technique (see: <http://www.iges.org/wcr/> & cfr. <http://www.iges.org/wcr/river/Niger.png>). In areas where there is strong low-level convergence between humid and dry (maritime and continental) air masses, such as along the Sahel region, or the "Dryline" of the Southern Great Plains of the US, virtually all the moisture for precipitation is supplied from the humid side of the convergence line. However, a posteriori water accounting methods like WAM or QIBT cannot resolve at the GCM grid scale which side of the convergence/precipitating grid cell the moisture came from, even with data at sub-diurnal temporal resolution. They tend to estimate approximately equal sources from each side of the line of low-level convergence. We have tried to correct for this in QIBT by changing the random selection of X,Y coordinates for starting parcels launched in areas of strong specific humidity gradients to skew heavily toward the humid side of the grid box - this did little to ameliorate the problem. We are currently involved in a funded project with M. Bosilovich and colleagues at NASA/GSFC where we will apply the QIBT technique to output from a version of the GEOS5 GCM that contains explicit tracing of water vapor. This will provide for the first time a cross-validation and, I suspect, expose this apparent cross-desert moisture advection as a spurious artifact of a posteriori water vapor tracking methods.”

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Response: We thank the reviewer for his comments, and suggestions regarding the potential spurious indication that there are large volumes of water coming from the Mediterranean region, and we look forward to the results of the cross-validation described in the upcoming research. We will include a disclaimer clarifying this potential spurious artifact, so that the reader is aware of the ongoing academic research that is seeking to clarify this information: “The strong contributions evident in the Mediterranean region are potentially a spurious artifact of the model being unable to resolve differences between humid and dry source regions. This issue has been identified in previous work, using similar methods, notably the work of Dirmeyer and Brubaker (2007).”

7. Comment: 10497, L8-10: The likelihood that trans-desert moisture advection is a much less important source than suggested by the analysis should be discussed here.

Response: Considering the information provided by the reviewer, we tend to agree with this observation. Interestingly, if trans-desert moisture advection is overestimated (for example, from the Mediterranean in Figure 3), then this implies that the reliance of sink regions on recycled moisture is even larger. However, we suggest the following text to follow 10497, L8-10: “Trans-desert moisture advection, such as that visible in Figure 3 appears to provide much of the moisture for many of the sink regions, however might be overestimated by a posteriori moisture tracking models such as the WAM model (Dirmeyer, 2011).”

8. Comment: Table 3: An interesting and unique table - could you add a column for total population in the precipitation-shed?

Response: This is an excellent suggestion, and the analysis will be included for each precipitationshed. The following text will be included to describe the population data: “Global, gridded population data were used to characterize the precipitationsheds in terms of the raw number of people. The NASA-sponsored Socioeconomic Data and Applications Center (SEDAC) provided the Gridded Population of the World (GPW),

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version 3 dataset, for the year 2000 (CIESIN 2005). The data were comprised of 400,000 sub-national units (ranging from sub-national to national), and were gridded at the 0.5 degree resolution. The 70% precipitationsheds were intersected with the gridded population dataset to estimate the number of people that occupy each precipitationshed (Table 3)."

Additional text will be added to describe and interpret the results.

9. Comment: Sec 5.3: This section provides a unique and instructive perspective that I have not seen before in water cycle studies like this. It is very interesting - more qualitative than quantitative, but that is OK as it is providing more of a social science perspective.

Response: We appreciate the recognition that this work is acknowledged as a useful contribution.

10. Comment: Sec 5.4: These assessments seem highly subjective. Please describe in more detail your criteria for each category (a decision tree or flow chart, perhaps), or couch this section more as "speculation" than "assessment".

Response: The authors acknowledge that this section is highly subjective, and dependent on the data we used. Rather than say speculation (which seems to convey a lack of method), we suggest the following text to replace the first sentence in Sec 5.4: "In order to determine the potential sink region vulnerability to changes in upwind land-use (and evaporation), current land-uses were compared with observed and expected changes in land-cover. Of notable importance was considering whether there was a high potential for rangelands to expand, because of the susceptibility of these landscapes to transition to degraded states (Milton et al., 1994)."

11. Comment: 10502, L11-13: Not a new idea, but laudable, yet politically \*very\* difficult, as the authors certainly must be aware. Nevertheless, the more research published showing the interconnectedness of our planet's resources, the more hope

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there is for breaking through short-sighted nationalistic policies.

Response: We agree with the author's comment, which is consistent with feedback from a separate reviewer. Therefore, we aim to clarify the sentence, with the following additional text to be included on p. 10502, L20: "Likewise, upwind and downwind stakeholders would both need to have their rights acknowledged, specifically rights to pursue their own livelihoods."

References:

Center for International Earth Science Information Network (CIESIN), Columbia University; and Centro Internacional de Agricultura Tropical (CIAT). 2005. Gridded Population of the World, Version 3 (GPWv3): Population Count Grid. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Available at <http://sedac.ciesin.columbia.edu/gpw> [Date of download: November 29, 2011]

Dirmeyer, P.A. and Brubaker, K.L. (2007) Characterization of the global hydrologic cycle from a back-trajectory analysis of atmospheric water vapor. *Journal of Hydrometeorology*. 8, 20-37

Dirmeyer, P. (2010): Interactive comment on "Analyzing precipitationsheds to understand the vulnerability of rainfall dependent regions" by P. W. Keys et al., *Biogeosciences Discussions*, 8, C4544-C4546, 2011.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., West, P. C., Balzer, C., Bennett, E. M., Carpenter, S. R., Hill, J., Monfreda, C., Polasky, S., Rockstrom, J., Sheehan, J., Siebert, S., Tilman, D., and Zaks, D. P. M.: Solutions for a cultivated planet, *Nature*, 478, 337-342, 10.1038/nature10452, 2011.

Milton, S., Dean, W., du Plessis, M., and Siegfried, W.: A conceptual model of arid rangeland degradation, *Bioscience*, 44, 70-76, 1994. 10499

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